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FOREIGN TECHNOLOGY DIVISION

PROCEEDINGS OF THE LENINGRAD ORDER OF LENIN ELECTROTECHNICAL INSTITUTE IMENI V.I. Ul'YANOV (LENIN)

(Selected Articles)

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Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
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М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*<u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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PROCEEDINGS OF THE LENINGRAD ORDER OF LENIN ELECTROTECHNICAL INSTITUTE IMENI V. I. UL'YANOV (LENIN).

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GENERATION AND COMPRESSION OF PHASE-KEYED RADIO SIGNALS IN AN ACOUSTOOPTICAL CORRELATOR.

The application of an acoustooptical correlator for the generation of complicated phase-keyed radio signals by the transformation of the spatial signal of the reference transparency into an electrical signal (this process we will call reading) is described ~~in~~ reference [1]. The electrical signal generated by this method is not completely identical to the signal of the reference transparency; therefore arises the question about the possibility of compressing this signal in the system of the acoustooptical correlator. In the present work this question is investigated theoretically and experimentally.

Fig. 1 depicts the diagram of an acoustooptical correlator, in one channel of which was generated a phase-keyed radio signal subsequently compressed in a second channel.

Utilizing the method of analysis of the work of the correlator presented in work [2], it is possible to show that the complex signal amplitude envelope at the output of the correlator

$$\dot{u}_1(t) = A e^{i(\varkappa-k)L} \int\limits_{t-\frac{2L}{V}}^{t} \dot{u}_s^{*}(\eta)\,\dot{u}_T(Vt - L - V\eta)\, e^{i(\varkappa-k)V\eta}, \qquad (1)$$

where $\dot{u}_s(\eta)$ - complex envelope of a radio signal entering the correlator; $u_T(x)$ - complex envelope of reference transparency signal; and k - phase constants of transparency and radio signal, respectively; V - velocity of ultrasound in acoustic line of light modulator; 2L - length of transparency; A - constant of system; * - sign of complex coupling.

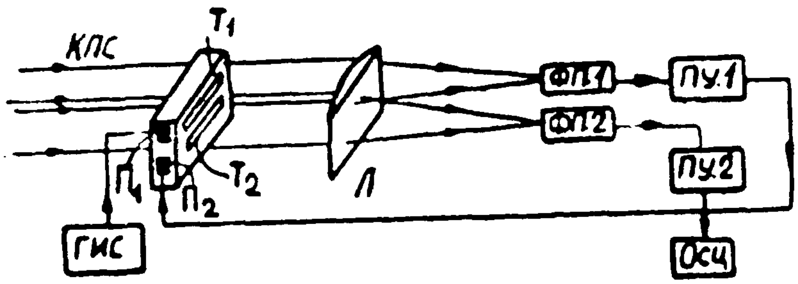

Fig. 1. Legend: KLS - collimated beam of light; T_1 and T_2 - first and second transparencies; P_1 and P_2 - first and second piezo electric transducers; L - cylindrical lens; FP_1 and FP_2 - first and second photoreceivers; PU_1 and PU_2 - first and second band-pass amplifiers; HIS - reading-pulse generator; Osc. - oscillograph.

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If in formula (1) we take $\dot{u}_s$ to mean that complex envelope of short radio pulse (reading signal), then $\dot{u}_1(t)$ will be the complex envelope of a radio signal generated in the first channel of a correlator; and the carrier frequency is equal to $\varkappa V$. If in formula (1) we take $\dot{u}_s$ to mean the complex envelope of the generated radio signal which enters the second channel, then expression (1) (changing the sign in the argument $\dot{u}_T(x)$ to the opposite one) will give the crosscorrelation function of the generated signal and the transparency signal. In this way for the

complex envelope of the correlation function it is possible to obtain the expression

$$\dot{R}(t) = \frac{A^2}{V} \int_{-L}^{L} \dot{u}_T(-x') \int_{-L}^{L} \dot{u}_s\left(t - \frac{2L}{V} - \frac{x'+x}{V}\right) \dot{u}_T(x)\, dx\, dx'. \quad (2)$$

Here $\dot{u}_s$ - complex envelope of the reading signal; it is accepted that the reading signal and transparency are matched, i.e., $\varkappa$ =k, and the signal delay in the second channel is absent. After introducing the spectra of complex envelopes of the transparency and reading signal $\tilde{\dot{u}}_T(p)$ and $\tilde{\dot{u}}_s(p)$, and by using convolution theorem, we convert (2) to the form

$$\dot{R}(t) = \frac{A^2}{V} \int_{-\infty}^{\infty} \tilde{\dot{u}}_s(\Omega)\, e^{-i\Omega\left(t - \frac{2L}{V}\right)} \tilde{\dot{u}}_T\left(-\frac{\Omega}{V}\right) \tilde{\dot{u}}_T\left(\frac{\Omega}{V}\right) d\Omega. \quad (3)$$

The last two factors are obviously the spectrum of the complex envelope of the autoccorrelation function of the transparency signal $\tilde{\dot{R}}_0(p)$; therefore, after writing for $\tilde{\dot{R}}_0(p)$ an inverse Fourier transform, we shall arrive after simplifications at the final formula for the complex envelope of the compressed signal

$$\dot{R}(t) = \frac{A^2}{V} \int_{-\infty}^{\infty} \dot{R}_0(x' + 2L - Vt)\, \dot{u}_s\left(\frac{x'}{V}\right) dx'. \quad (4)$$

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Formula (4) show that the complex envelope of the crosscorrelation function of the generated signal and transparency signal is the complex envelope of the autocorrelation function of the transparency signal passed through a linear filter with an impulse function equal to $\dot{u}_s(t)$ - the complex envelope of the reading signal, and it makes it possible to calculate the form of the complex envelope of signals compressed in the correlator.

Fig. 2 presents the results of calculations for compression of signals phase-keyed according to the 13-element Barker code. From the examination of graphs it is possible to make the following conclusions relative to the crosscorrelation function of a read signal and transparency:

1. The ration of the major lobe to the signed lobes is retained.

2. The major lobe decreases in absolute value and the more so as the duration of the reading pulse increases.

3. The structure of side lobes changes slightly: zeroes come in, and the maximums somewhat decrease.

4. The duration of the entire function increases by twice the duration of the reading signal.

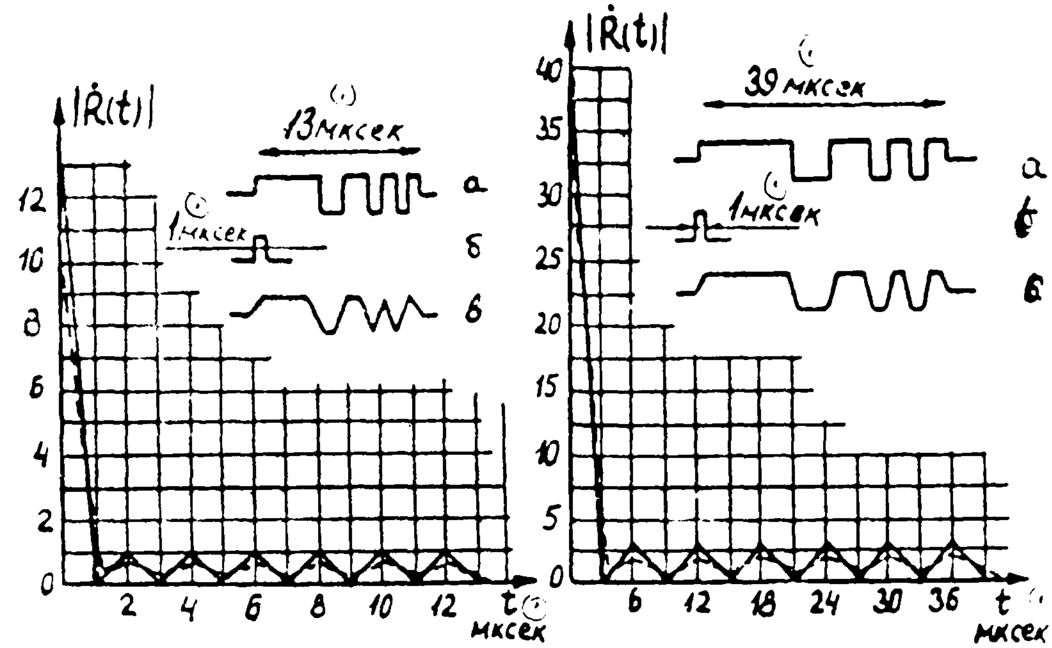

Fig. 2. Legend: ——— - autocorrelation function of 13-element Barker code (transparency); . . . - crosscorrelation function of transparency signal and read signal; a, b, c - complex envelopes of transparency signal, reading signal and read signal.

Key: (1). µs.

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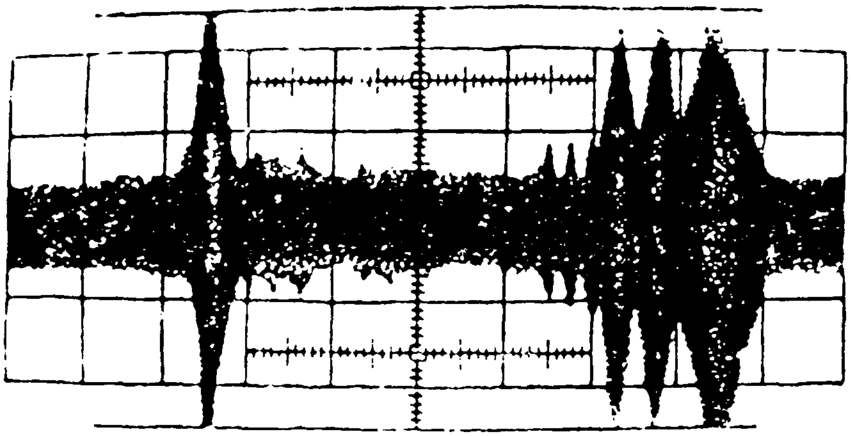
We experimentally investigated the reading of signals phase-keyed according to the 13-element Barker code and their subsequent compression on the apparatus in Fig. 1. Shown in Fig. 3a,b oscillograms of read and compressed signals. The difference between the experimentally observed correlation function and the calculated one is explained by the imperfect form of the read

signal, which was the consequence of distortions introduced by he band-pass amplifier; this deficiency, however, can be removed.

Thus, theoretical and experimental investigation shows the possibility of compressing the complex phase-keyed signals generated in an acoustic correlator.

a)



b)

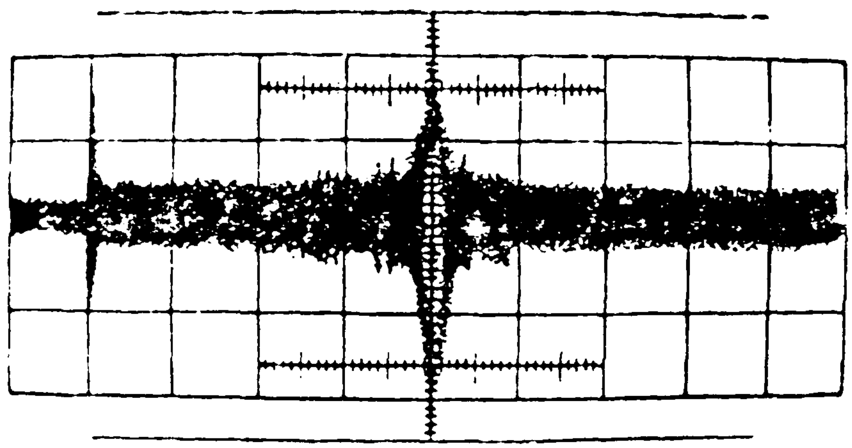


Fig. 3.

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SYNTHESIS OF THE REFERENCE TRANSPARENCY FOR THE GENERATION OF FREQUENCY-MODULATED RADIO SIGNALS BY THE METHOD OF OPTICAL CORRELATION.

K. P. Naumov.

For the optical correlation methods of the generation of complex radio signals it is characteristic to use a reference transparency, whose structure determines the structure of the generated signal. If the question of the reference transparency structure necessary for obtaining a required radio signal during the generation of phase-keyed radio signals (1), is solved elementarily, in the case of the generation of radio signals with a continuous complex envelope (FM) this question requires special examination. In the present work is solved the problem of synthesizing a complex envelope of the transparency function of a transparency for a specified continuous complex envelope of the generated signal. Let $\dot{u}_T(x)$ be the complex envelope of the transparency function of a transparency; g(x) - a Fourier transform from G(p) - the aperture function in the region of spatial frequencies, with G is equal to zero outside of the interval $p_0 - p \leqslant p \leqslant p_0 + \Delta p$ and to one within this interval; let the input signal of the correlator be a radio pulse with a rectangular envelope with a duration of t_0 (reading pulse); then, following

[2], it is possible to show that the complex envelope of the output signal is

$$\dot{I}(t) = A \int_{t-\frac{2L}{V}}^{t} \dot{u}_T(Vt - L - V\eta)\,\varphi(\eta)\,e^{-i\varkappa V\eta}\,d\eta, \qquad (1)$$

where $\varkappa$ - phase constant of the transparency, equal to the phase constant of the radio pulse of reading; V - speed of ultrasound in acoustic line of light modulator; 2L - aperture of modulator; A - constant of system, and $\varphi(\eta)$- known function with the form:

$$\varphi(\eta) = \int_0^{t_0} g(V\eta' - V\eta)\,e^{i\varkappa V\eta'}\,d\eta'.$$

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Equation (1) is an integral equation for an unknown complex envelope of a transparency $\dot{u}_T(x)$ - with a specified complex envelope of the output radio signal $\dot{I}(t)$. It is known [3] that equation (1) - a fundamental integral equation of the theory of linear instruments - has a unique solution if $\dot{u}_T(x)$ is finite and square-intervable. Since these conditions in our case are satisfied, then there is a unique solution of equation (1), which can be found by utilizing a Fourier transform and the convolution theorem. We will obtain after simple calculations

$$\dot{u}_T(x) = \frac{1}{2\pi A t_0} \int_{(p_0-\Delta p-\varkappa)V}^{(p_0+\Delta p-\varkappa)V} \frac{\dot{\tilde{I}}(\Omega)\,e^{-i\left(L-x-\frac{Vt_0}{2}\right)\frac{\Omega}{V}}}{\operatorname{sinc}\left(\frac{\Omega t_0}{2}\right)}\,d\Omega. \qquad (2)$$

In formula (2) $\dot{\tilde{I}}(\Omega)$ designates the complex conjugated spectrum of the function $\dot{I}(t)$, and sin ct=sin t/t. Formula (2) gives in general form the unique solution for the complex envelope of the transparent $\dot{u}_T(x)$, expressed by the spectrum of the complex envelope of the required radio signal and by the parameters of the reading pulse. Expression (2) can e simplified in the most important case of signals with a high compression coefficient, after using for calculation of the signal spectrum the stationary phase method [4]. Let the complex envelope of the radio signal be written in the form:

$$\dot{I}(t) = b(t)\, e^{i\Theta(t)}, \tag{3}$$

where $\dot{b}(t)$ - amplitude envelope, and $\Theta(t)$ - phase function, where

$$b(t) = \begin{cases} 1, & t \in [0, T], \\ 0, & \bar{t} \in [0, T]. \end{cases}$$

then expression (2) can be represented in the form

$$\dot{u}_T(x) = \frac{e^{i\frac{\pi}{4}}}{\sqrt{2\pi}\, A t_0} \times$$

$$\int_{-\pi V}^{\pi V} \frac{b(t_s) \exp\left\{-i\left[\Theta(t_s) + \left(L + x - \frac{V t_0}{2}\right)\frac{\Omega}{V} - \Omega t_s\right]\right\} d\Omega}{\sqrt{\Theta''(t_s)}\, \sin c\, \frac{\Omega t_0}{2}}, \tag{4}$$

where t_s - solution of equation $\Theta'(t) = \Omega$.

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To the integral in (4) it is possible to again apply the stationary phase method and we will obtain finally:

$$s_\tau(x) = \frac{\exp\left\{-i\left[\Theta(t_s(\Omega_s)) + \left(L + x - \frac{Vt_0}{2}\right)\frac{\Omega_s}{V}\Omega_s t_s(\Omega_s)\right]\right\}}{At_0\sqrt{\Theta''(t_s\Omega_s)}\sqrt{\frac{d^2\Theta}{dt_s^2}\left(\frac{dt_s}{d\Omega_s}\right)^2 - 2\frac{dt_s}{d\Omega_s}}\sin c\frac{\Omega_s t_0}{2}} \qquad (5)$$

where Ω_s - solution of the equation

$$\frac{d\Theta}{dt_s}\frac{dt_s}{d\Omega} + \left(L + x - \frac{Vt_0}{2}\right)\frac{1}{V} - t_s(\Omega) - \Omega\frac{dt_s}{d\Omega} = 0. \qquad (6)$$

Formula (7) makes it possible to calculate from the known phase function of the radio signal the complex envelope of the transparency function of the transparency; it is accurate with the aperture width in the frequency range 2 p larger than the width of the main part of the spectrum of the transparency.

Let us examine a special case of a LFM radio signal, i.e., let us assume $\Theta(t) = \gamma t^2/2$. In this case from equations (5) and (6). it is easy to derive:

$$\dot{u}_\tau(x) = \frac{\exp\left\{-i\left[\frac{\gamma}{2V^2}\left(L + x - \frac{Vt_0}{2}\right)^2\right]\right\}}{At_0\sin c\frac{\gamma t_0}{2}\left(\frac{L}{V} + \frac{x}{V} - \frac{t_0}{2}\right)}. \qquad (7)$$

It is simplified when $\gamma T t_0 \ll 1$ (7):

$$\dot{u}_{T}(x) = c\exp\left\{i\frac{\gamma}{2V^2}\left(L + x - \frac{Vt_0}{2}\right)^2\right\}.$$

consequently, for small deviations and durations of the reading signal the structure of the transparency coincides with the structure of the signal; otherwise additional amplitude modulation of the transparency is necessary.

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